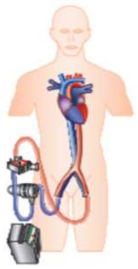
ECMO

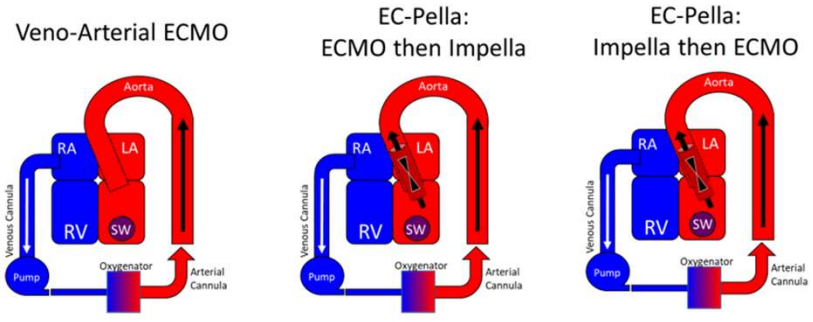


Giselle A. Baquero MD
Interventional Structural Cardiologist
Assistant Professor of Medicine
University of Hawaii

1

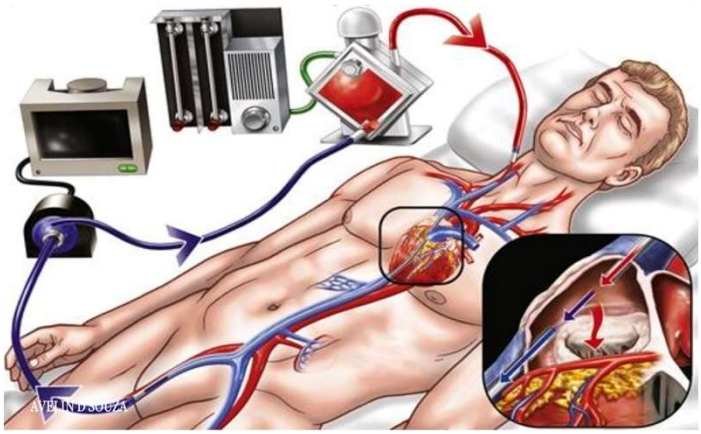
Objectives

- Understand ECMO as Boon to the intensivist



2

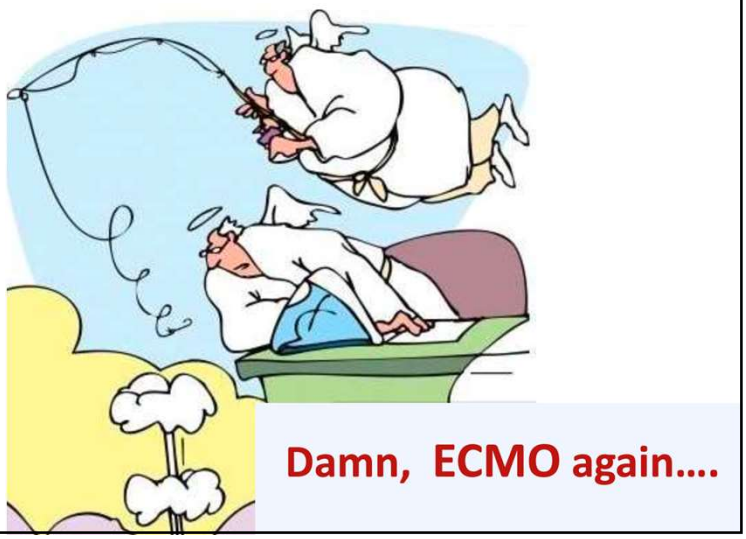
What is ECMO?



3

Goals

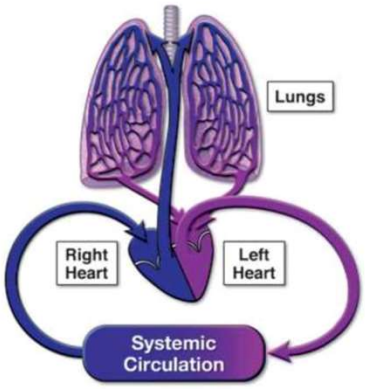
- Ensure adequate oxygenation
- Does NOT treat the heart or lungs → time to REST and RECOVER
- Ventilatory settings → reduced to levels that will not damage the lung
- Help reduce pressor requirements



4

Principle

- Desaturated blood drained → venous cannula
- CO2 → removed, O2 → added through extracorporeal device
- Blood returns to systemic circulation via another vein (VV ECMO) or artery (VA ECMO)

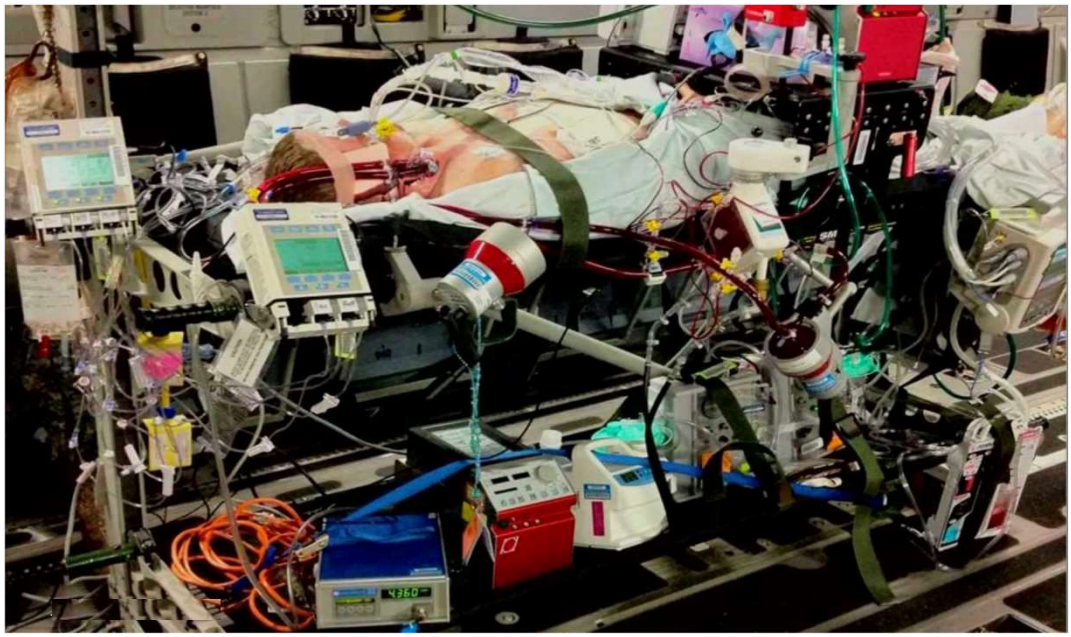


ECMO :

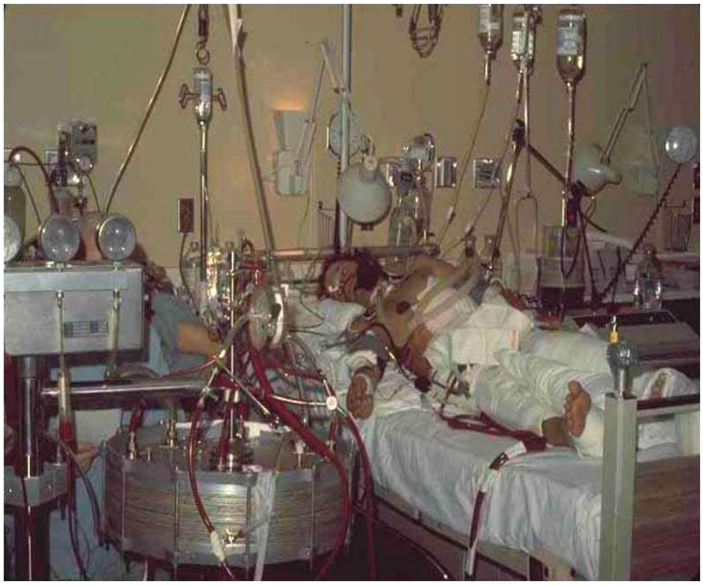
O_2 delivery

- Oxygenation
- CO_2 removal
- Circulatory flow

5



6



Hill JD, et al. NEJM ,1972

7

Applications

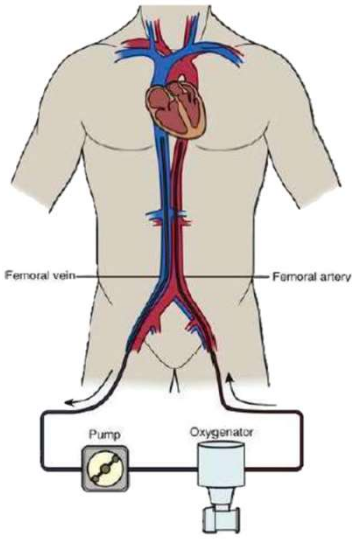
Bridge to:

- Recovery
- Decision making
- Solution: LVAD/transplant

8

Types

- Venous-venous (VV ECMO)
  - ✓ Severe respiratory failure
  - ✓ Central vein→ ECMO → to central vein
- Venous-arterial (VA ECMO)
  - ✓ Severe cardiac failure +/- respiratory failure
  - ✓ Central vein → ECMO → central artery



9

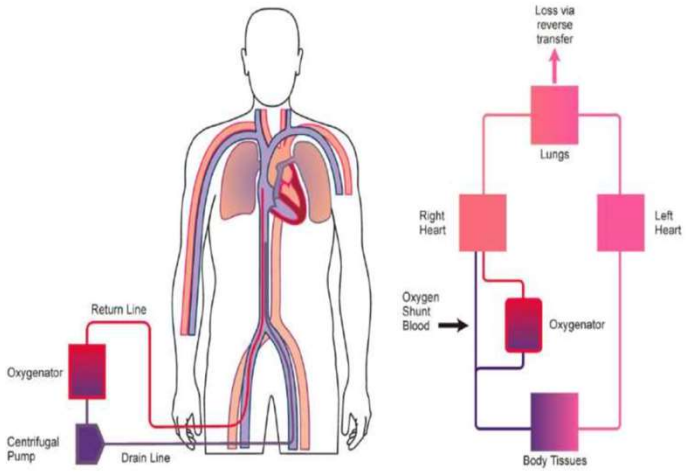
VV-ECMO Configurations

Femoro-Femoral

- ✓ Access Cannula(21-25 Fr): 8-10 cm below diaphragm
- ✓ Return cannula(21-25 Fr): Into RA directed towards TV
- ✓ Advantages: Quick,Safe to insert,easy to secure cannulae, circuit pressures will allow connection to CRRT
- ✓ Disadvantages: Limited maximum flow rates, Patient remains bed bound

High Flow

- ✓ Advantages: Allows high circuit flows, required when single access cannula circuit flow is inadequate to maintain gas exchange
- ✓ Disadvantages: Occupies 3 veins, Complex to secure, Air embolism

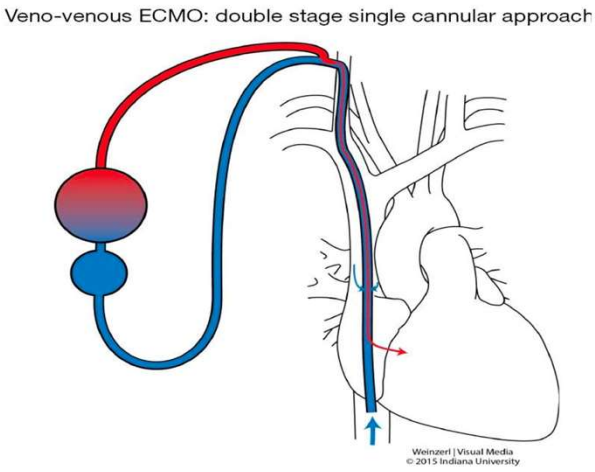


10

VV-ECMO Configurations

Two stage single cannula

- ✓ Access cannula: Single with two lumens (IVC and SVC)
- ✓ Return cannula: Between two access ports
- ✓ Advantages: Single vein cannulation, allows movement from bed/ambulation
- ✓ Disadvantages: Difficult technique, difficult to start CRRT



11

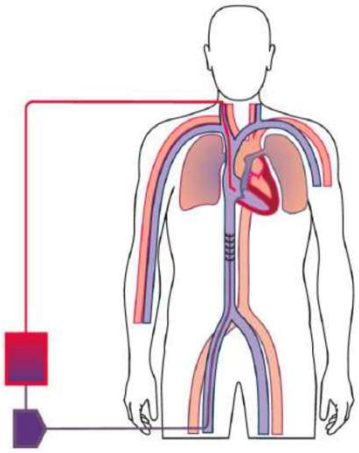
VV-ECMO Configurations

- Most common VV-ECMO

Femoro-Jugular

- ✓ Access Cannula(21-25 Fr): Via femoral vein, just below infero cavo atrial junction
- ✓ Return (short cannula,19-23 Fr): Via IJV rt into RA directed towards TV
- ✓ Advantages: Can provide adequate flows, safe to insert, circuit pressures will allow connection to CRRT
- ✓ Disadvantages: Difficult to secure cannulae ,Patient remains bed bound

- Can provide 5-7L/min



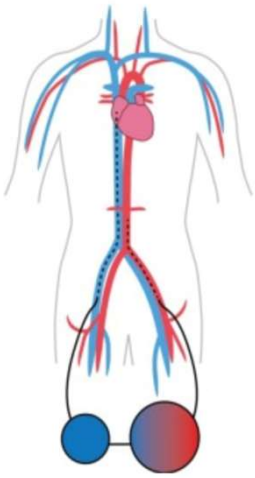
12

VA-ECMO Peripheral cannulations

- Most common VA-ECMO

Standard Femoro Femoral

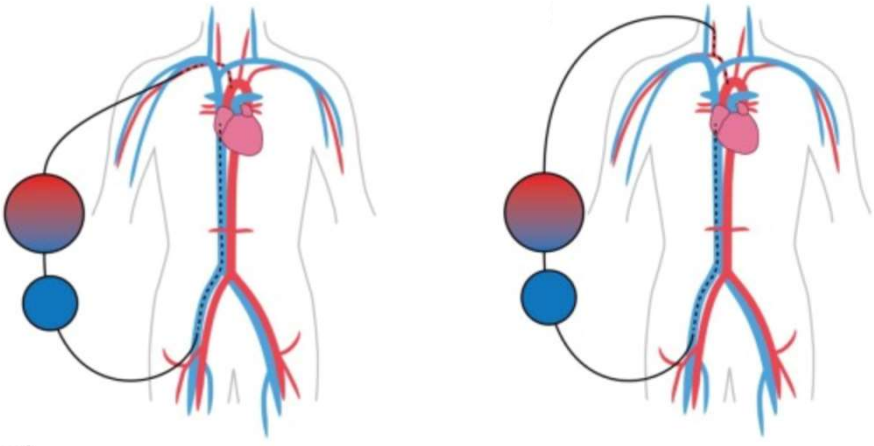
- ✓ Access Cannula (21-25 F): Via femoral vein with the tip sited within rt atrium
- ✓ Return Cannula(short,17-21 Fr): Tip lies into the common iliac artery or lower aorta
- ✓ Distal perfusion return cannula (9Fr): Inserted antegrade into the common femoral/superficial femoral artery
- ✓ Advantages: Provides full cardiac support, can support CRRT
- ✓ Disadvantages: Risk of differential hypoxia



Makdisi G, et al. Journal of Thoracic Disease. 2015

13

VA-ECMO Peripheral cannulations



Makdisi G, et al. Journal of Thoracic Disease. 2015

14

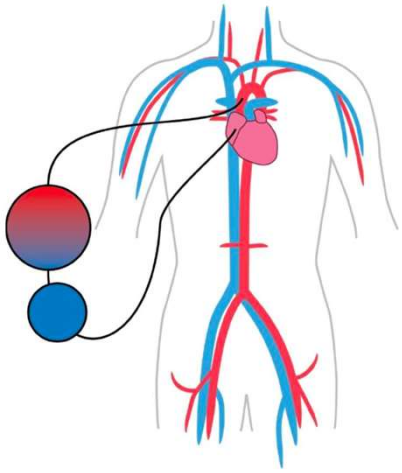
VA-ECMO Peripheral cannulations

Central: Specialised Cannula

- ✓ Access Cannula (> 30 F): Wire reinforced ,sited within the rt atrium through atial appendage
- ✓ Return Cannula((> 30 F): Dacron tipped and sewn directly into the proximal aorta
- ✓ Advantages: Provides full cardiac support, can support CRRT, No differential Hypoxia
- ✓ Disadvantages: Requires sternotomy, Bleeding

High flow

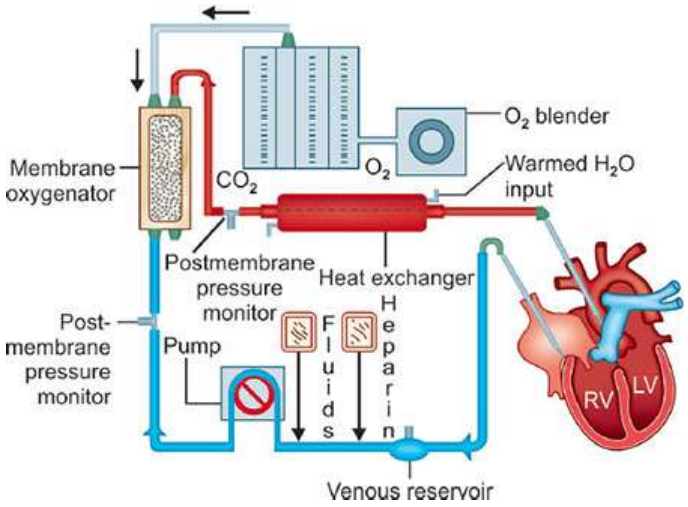
- ✓ Same bifemoral approach as standard technique, with additional short access cannula in IJV ,tip in IVC
- ✓ Advantages: Used to minimize differential hypoxia



Makdisi G, et al. Journal of Thoracic Disease. 2015

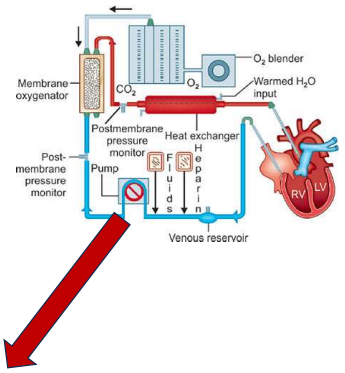
15

Components of ECMO

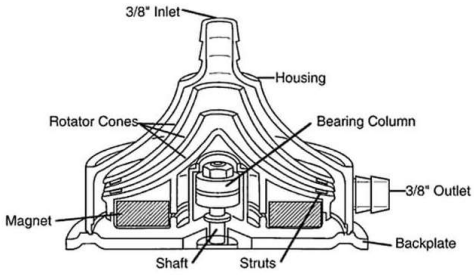


16

Centrifugal Pumps

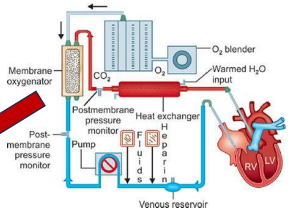


- Roller pumps → centrifugal pumps
- Perfusion pressure is controlled by RPM (0-4000 RPM)
- Deliver flow up to 8L/min
- Up to 21 days

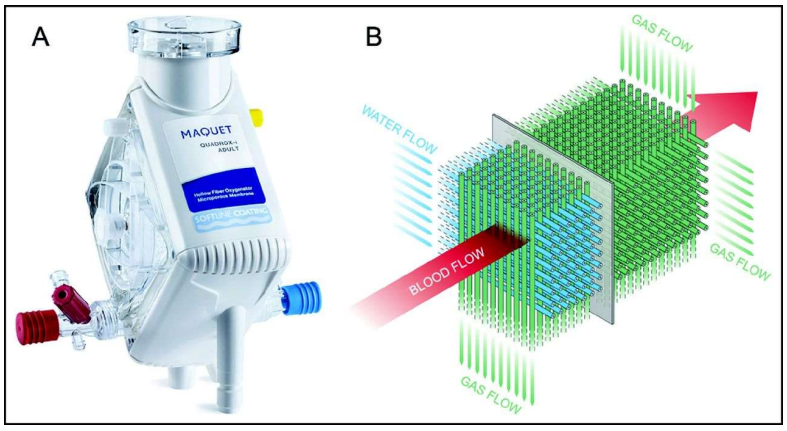


17

Membrane Oxygenator



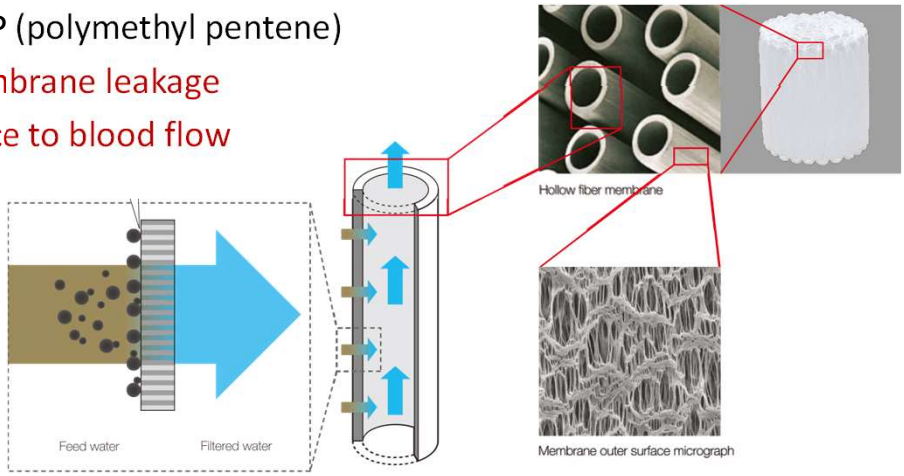
- Gas exchange device



18

Mechanism of gas exchange

- Previously silicon membrane
- Hollow Fibre PMP (polymethyl pentene)
  - ✓ Minimal membrane leakage
  - ✓ Low resistance to blood flow

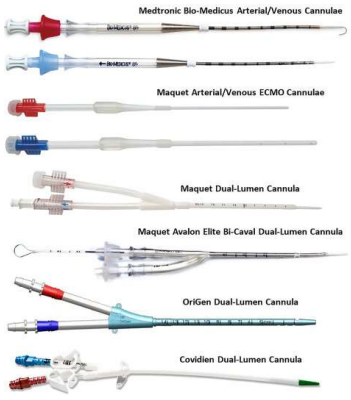


19

Component of ECMO Set Up

- **Central Unit Controller**

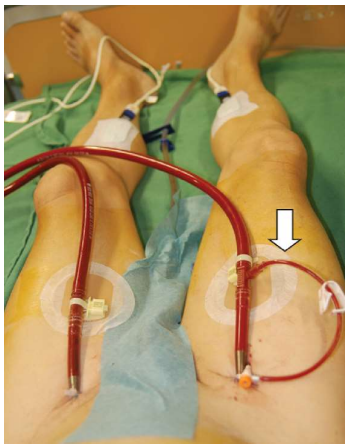
✓Controller panel for pressure monitoring and blood gas monitoring



20

Cannula after placement

- Securing access and returning lines



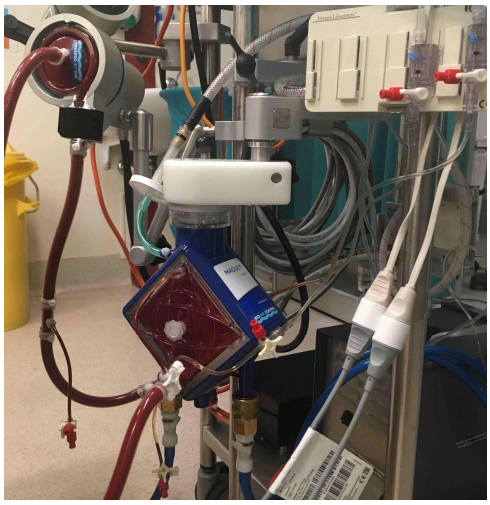
21

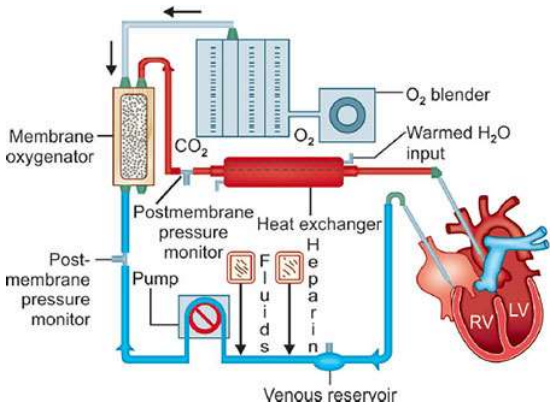
Factors Determining Gas Exchange

- **O_2 Exchange Depends On:**
  - ✓Type of membrane and diffusion characteristics
  - ✓Thickness of the blood pathway
  - ✓Surface area of the membrane
  - ✓FiO_2 in the gas phase
  - ✓Rate of blood flow
- **CO_2 Exchange Depends On:**
  - ✓Difference in CO_2 concentration between blood and gas
  - ✓Size of membrane
  - ✓Fresh gas flow
  - ✓Blood pathway thickness
  - ✓Blood flow rate

22

ECMO Set Up





23

Factors Deciding ECMO Candidacy

Murray score

= average score of all 4 parameters

Parameter / Score	0	1	2	3	4
PaO2/FIO2 (On 100% Oxygen)	≥300mmHg ≥40kPa	225-299 30-40	175-224 23-30	100-174 13-23	<100 <13
CXR	normal	1 point per quadrant infiltrated			
PEEP	≤5	6-8	9-11	12-14	≥15
Compliance (ml/cmH2O)	≥80	60-79	40-59	20-39	≤19

24

Indications for ECMO

Intensive Care Med (2013) 39:275–281
DOI 10.1007/s00134-012-2747-1

ORIGINAL

Federico Pappalardo
Marina Pieri
Teresa Greco
Nicolò Patroniti
Antonio Pesenti
Antonio Arcadipane
V. Marco Ranieri
Luciano Gattinoni
Giovanni Landoni
Bernhard Holzgraefe
Gernot Beutel
Alberto Zangrillo
on behalf of the Italian ECMOnet

Predicting mortality risk in patients undergoing venovenous ECMO for ARDS due to influenza A (H1N1) pneumonia: the ECMOnet score

25

ECMOnet

- 60 pts H1N1 pandemic. 28 → ECMO
- Survival rate 68 %.
- Significant predictors of death before ECMO
  - ✓ Hospital length of stay (OR = 1.52, 95 % CI 1.12-2.07, p = 0.008)
  - ✓ Bilirubin (OR = 2.32, 95 % CI 1.52-3.52, p < 0.001)
  - ✓ Creatinine (OR = 7.38, 95 % CI 1.43-38.11, p = 0.02)
  - ✓ Hematocrit values (OR = 0.82, 95 % CI 0.72-0.94, p = 0.006)
  - ✓ MAP (OR = 0.92, 95 % CI 0.88-0.97, p < 0.001)

The ECMOnet score was developed based on these variables

✓Score of 4.5 → cutoff for mortality risk prediction

26

BMC Health Services Research

BioMed Central

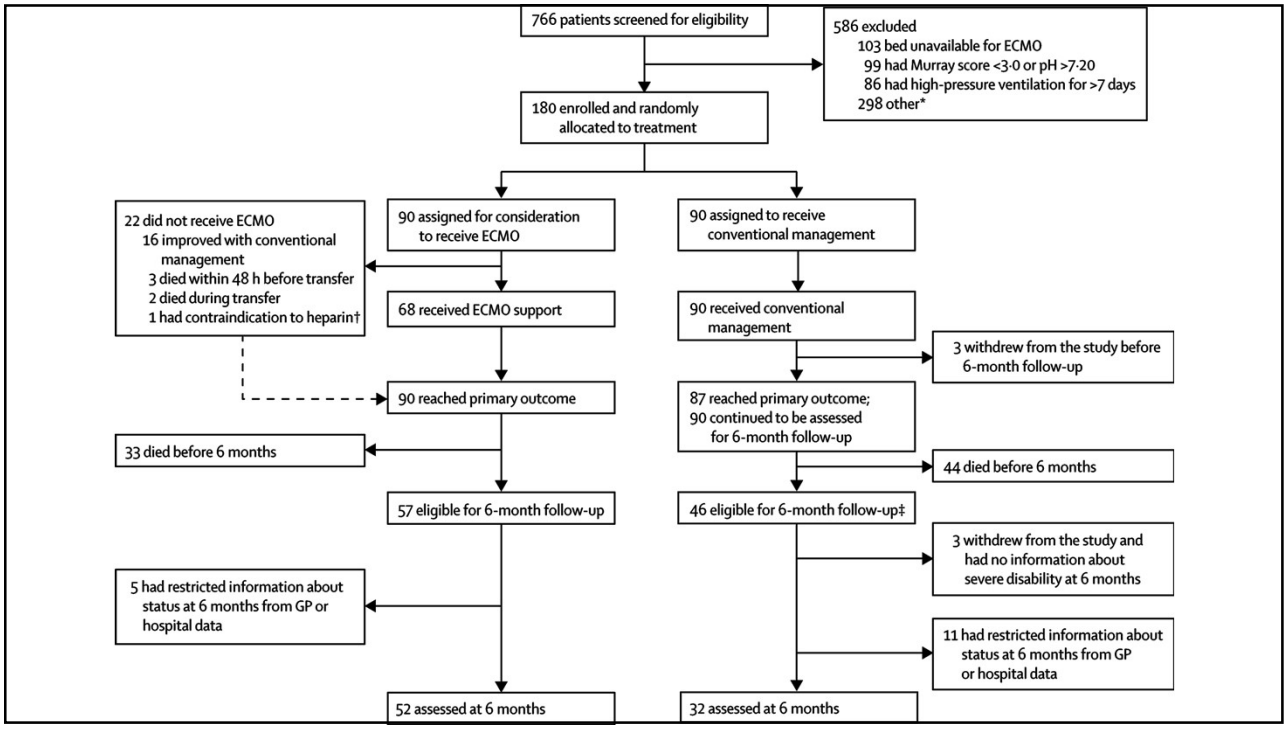
Study protocol

Open Access

CESAR: conventional ventilatory support vs extracorporeal membrane oxygenation for severe adult respiratory failure

Giles J Peek*[1], Felicity Clemens[2], Diana Elbourne[2], Richard Firmin[1], Pollyanna Hardy[2,3], Clare Hibbert[5], Hilliary Killer[1], Miranda Mugford[4], Mariamma Thalanany[4], Ravin Tiruvoipati[1], Ann Truesdale[2] and Andrew Wilson[6]

27



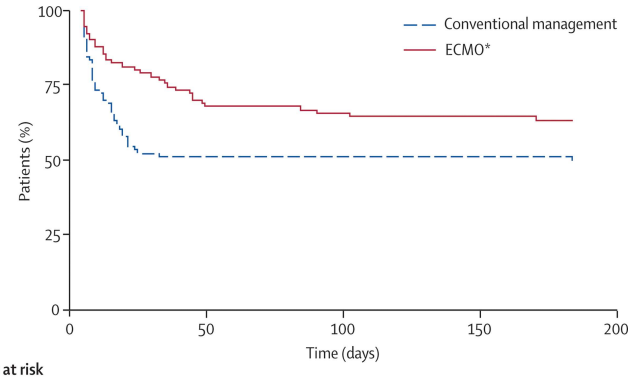
28

CESAR

- ECMO survival 63% vs conv vent 47%
- Relative risk reduction 0.69

(0.05-0.97; *p = 0.03*)

- NNT to prevent 1 death = 6



Patients at risk					
Conventional management	90	45	44	44	0
ECMO*	90	61	59	58	0

29

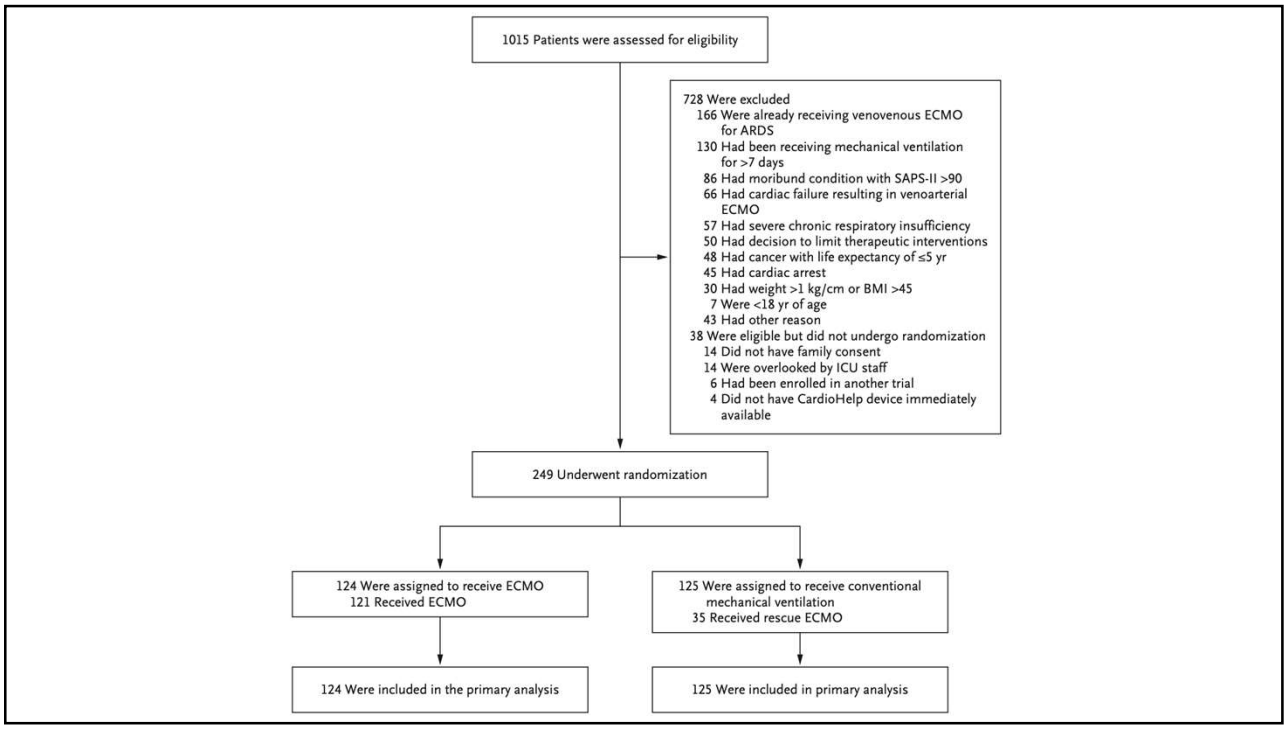
The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MAY 24, 2018 VOL. 378 NO. 21

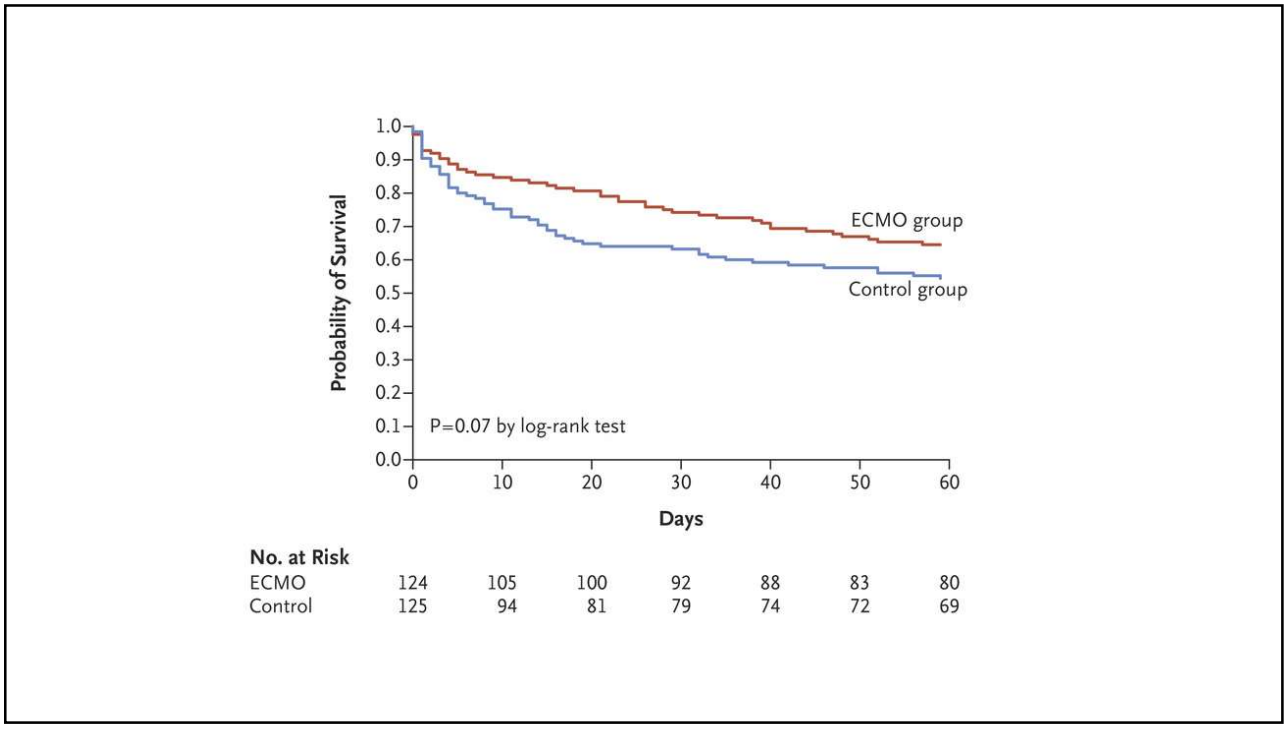
Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome

A. Combes, D. Hajage, G. Capellier, A. Demoule, S. Lavoué, C. Guervilly, D. Da Silva, L. Zafrani, P. Tirot, B. Veber, E. Maury, B. Levy, Y. Cohen, C. Richard, P. Kalfon, L. Bouadma, H. Mehdaoui, G. Beduneau, G. Lebreton, L. Brochard, N.D. Ferguson, E. Fan, A.S. Slutsky, D. Brodie, and A. Mercat, for the EOLIA Trial Group, REVA, and ECMONet*

30


1015 Patients were assessed for eligibility
728 Were excluded
166 Were already receiving venovenous ECMO for ARDS
130 Had been receiving mechanical ventilation for >7 days
86 Had moribund condition with SAPS-II >90
66 Had cardiac failure resulting in venoarterial ECMO
57 Had severe chronic respiratory insufficiency
50 Had decision to limit therapeutic interventions
48 Had cancer with life expectancy of ≤5 yr
45 Had cardiac arrest
30 Had weight >1 kg/cm or BMI >45
7 Were <18 yr of age
43 Had other reason
38 Were eligible but did not undergo randomization
14 Did not have family consent
14 Were overlooked by ICU staff
6 Had been enrolled in another trial
4 Did not have CardioHelp device immediately available
249 Underwent randomization
124 Were assigned to receive ECMO
121 Received ECMO
125 Were assigned to receive conventional mechanical ventilation
35 Received rescue ECMO
124 Were included in the primary analysis
125 Were included in primary analysis

31


Probability of Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ECMO group
Control group
P=0.07 by log-rank test
0
10
20
30
40
50
60
Days
No. at Risk
ECMO 124 105 100 92 88 83 80
Control 125 94 81 79 74 72 69

32

Indications for ECMO

	ELSO	ECMOnet	CESAR	EOLIA
Indication	Mortality>80% P/F<80 Fi>.90 Murray score 3-4	OI>30 P/F<70 PEEP ≥15 for patients in ECMO center pH<7.25 x ≥ 2 hrs	Potentially reversible respiratory failure Murray score ≥ 3	P/F <50 Fi>0.8 x >3hrs P/F<80 Fi>0.8 x>6hrs pH<7.25 for >6hrs (RR increased to 35) adjusted to keep Pplat <32
Consideration for ECMO	Mortality>50% P/F<150 Fi>90 Murray score 2-3	P/F<100 PEEP ≥ 10 patients awaiting transfer to ECMO center	Murray score ≥2.5	
Contraindication	Condition incompatible with life Pre-existing conditions Age Futility MV>7d	Contraindication to anticoagulation Severe disability MV>7 days	PIP >30 Fi>0.8 MV>7 days Contraindication to anticoagulation Contraindication to ongoing treatment	Mechanical Ventilcation ≥7 days Age<18 years Pregnancy BMI>45 Hx of Heprin Induced Thrombocytopenia Chronic severe respiratory disease SAPS II>90 Moribund Malignancy predicted survival<5 years ECMO cannulation not possible

33

Indications for ECMO

- Reversible Respiratory Failure
  - ✓ ARDS
  - ✓ Severe Pneumonia
  - ✓ Severe acute asthma
  - ✓ Chemical and inhalation hypersensitivity pneumonitis
  - ✓ Near drowning
  - ✓ Post traumatic lung contusion
  - ✓ Bronchiolitis Obliterans
  - ✓ Autoimmune lung disease, vasculitis, GPS

34

Indications for ECMO

- Irreversible Chronic Respiratory Failure
  - ✓ Indicated as a bridge ONLY when:
    - Patient is for lung assist device PAL (paracorporeal artificial lung)
    - Patient waiting for lung transplant

35

Contraindications

- **Relative**
  - ✓ Prolonged Mechanical ventilation(>14days)
  - ✓ Severe chronic lung disease
  - ✓ Un-witnessed arrest or CPR for 30 minutes
  - ✓ Uncontrollable metabolic acidosis
  - ✓ Immunosuppression
  - ✓ Severe coagulopathy disorder
  - ✓ <2000gms in weight
- **Absolute**
  - ✓ Significant neurological injury
  - ✓ Activebleeding/coagulation disorder
  - ✓ Terminal disease with short life expectancy
  - ✓ Cerebral Hemorrhage
  - ✓ Genetic Abnormalities
  - ✓<34 weeks gestational age

36

ECMO Likely to FAIL

- Wrong ECMO configuration
  - ✓ Chronic respiratory/cardiac disease with NO hopes of recovery/transplant
  - ✓ Out of hospital ECMO-CPR >50mins
  - ✓ Severe aortic regurgitation/type A aortic dissection
  - ✓ Refractory septic shock in adults with preserve ejection fraction
  - ✓ Allogenic stem cell transplant
  - ✓ Age >70 with severe ARDS
  - ✓ ARDS with multiple organ failure
  - ✓ Prolonged pre-ECMO mechanical ventilation

37

Things to Think About

- Mechanical ventilation must be continued during ECMO support to try to maintain oxygen saturation of blood ejected from the left ventricle to at least above 90%.
- ECMO flow can be very volume dependent
- ECMO flow will drop:
  - ✓ Hypovolemia
  - ✓ Cannula malposition
  - ✓ Pneumothorax
  - ✓ Pericardial tamponade

38

Cardiorespiratory Physiology VV-ECMO

- Volume of blood removed and that returned to the circulation are equal
  - ✓ Minimal impact upon preload
- Indirectly affects cardiac function
  - ✓ The improvement in oxygenation and carbon dioxide clearance on ECMO reduces pulmonary vasoconstriction, thus reducing RV work and improving performance
  - ✓ As extracorporeal gas exchange reduces the reliance on intrinsic pulmonary function, the pressures delivered to the lungs by mechanical ventilation can be significantly reduced (rest lung settings) reduces RV afterload
- VV-ECMO has no direct effect on left ventricular (LV) function
  - ✓ Improved LV performance may also be observed, as a result of improved RV performance, due to ventricular interdependence

39

Cardiorespiratory Physiology VV-ECMO

- Blood flow at the rate of 3-6l/min for acceptable arterial oxygenation
  - ✓ Aim is to provide ECMO pump flows equal to/or more than 60% of the patients cardiac output with saturation of > 88% & PaCO2 b/w 30-40
  - ✓ Common for patients on V-V ECMO to have PO2 in range of 55-90 mmHg
- Oxygenation depends on
  - ✓ Cardiac output
  - ✓ Hemoglobin concentration
  - ✓ Oxygen saturation

40

ECMO Indications for Cardiac Failure

- Cardiogenic shock (Definition)
  - ✓ Inadequate tissue perfusion manifested as hypotension and low cardiac output despite adequate intravascular volume
  - ✓ Shock persist despite volume administration, inotropes and vasoconstrictors and intraaortic balloon counterpulsation if appropriate

41

Cardiogenic Shock Definition

- Cardiogenic Shock is a complex and heterogenous clinical syndrome characterized by hypotension and hypoperfusion due to acute cardiac disease
- RCTs in CS patients have not been able to identify survival benefits of MCS devices when applied in different populations of CS patients

AMI-CS: STEMI or NSTEMI

HF-CS: de-novo or ACHF

- Not all shock is created equal

42

Cardiogenic Shock Definition

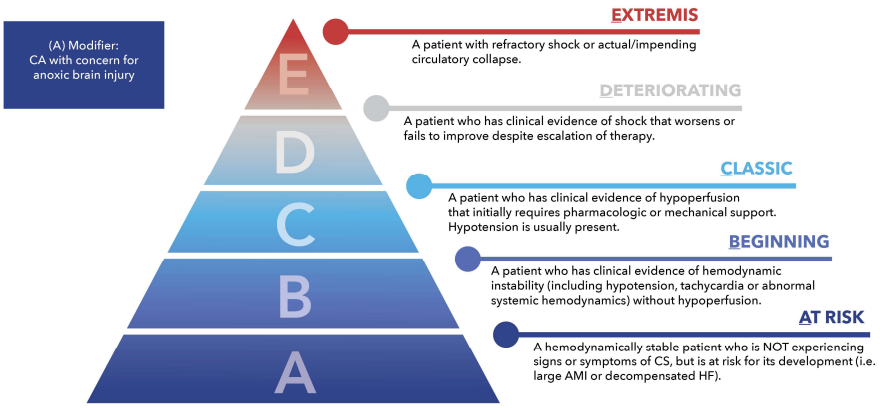
SCAI clinical expert consensus statement on the classification of cardiogenic shock

This document was endorsed by the American College of Cardiology (ACC), the American Heart Association (AHA), the Society of Critical Care Medicine (SCCM), and the Society of Thoracic Surgeons (STS) in April 2019

David A. Baran MD, FSCAI (Co-Chair)[1] | Cindy L. Grines MD, FACC, FSCAI[2*] | Steven Bailey MD, MSCAI, FACC, FACP[3] | Daniel Burkhoff MD, PhD[4] | Shelley A. Hall MD, FACC, FHFSA, FAST[5] | Timothy D. Henry MD, MSCAI[6] | Steven M. Hollenberg MD[7‡] | Navin K. Kapur MD, FSCAI[8] | William O'Neill MD, MSCAI[9] | Joseph P. Ornato MD, FACP, FACC, FACEP[10] | Kelly Stelling RN[1] | Holger Thiele MD, FESC[11] | Sean van Diepen MD, MSc, FAHA[12†] | Srihari S. Naidu MD, FACC, FAHA, FSCAI (Chair)[13]

43

Cardiogenic Shock Definition



Diepen et al. 2019

44

TABLE 1 Descriptors of shock stages: physical exam, biochemical markers and hemodynamics

Stage	Description	Physical exam/bedside findings	Biochemical markers	Hemodynamics
A At risk	A patient who is not currently experiencing signs or symptoms of CS, but is at risk for its development. These patients may include those with large acute myocardial infarction or prior infarction acute and/or acute on chronic heart failure symptoms.	Normal JVP Lung sounds clear Warm and well perfused • Strong distal pulses • Normal mentation	Normal labs • Normal renal function • Normal lactic acid	Normotensive (SBP≥100 or normal for pt.) If hemodynamics done • cardiac index ≥2.5 • CVP <10 • PA sat ≥65%
B Beginning CS	A patient who has clinical evidence of relative hypotension or tachycardia without hypoperfusion.	Elevated JVP Rales in lung fields Warm and well perfused • Strong distal pulses • Normal mentation	Normal lactate Minimal renal function impairment Elevated BNP	SBP <90 ***OR*** MAP <60 ***OR*** >30 mmHg drop from baseline Pulse ≥100 If hemodynamics done • cardiac index ≥2.2 • PA sat ≥65%
C Classic CS	A patient that manifests with hypoperfusion that requires intervention (inotrope, pressor or mechanical support, including ECMO) beyond volume resuscitation to restore perfusion. These patients typically present with relative hypotension.	***May Include Any of:*** Looks unwell Panicked Ashen, mottled, dusky Volume overload Extensive rales Killip class 3 or 4 BiPap or mechanical ventilation Cold, clammy Acute alteration in mental status Urine output <30 mL/h	***May Include Any of:*** Lactate ≥2 Creatinine doubling ***OR*** >50% drop in GFR Increased LFTs Elevated BNP	***May Include Any of:*** SBP <90 ***OR*** MAP <60 ***OR*** >30 mmHg drop from baseline ***AND*** drugs/device used to maintain BP above these targets Hemodynamics • cardiac index <2.2 • PCWP >15 • RAP/PCWP ≥0.8 • PAPI <1.85 • cardiac power output ≤0.6
D Deteriorating/ doom	A patient that is similar to category C but are getting worse. They have failure to respond to initial interventions.	***Any of stage C***	***Any of Stage C AND:*** Deteriorating	***Any of Stage C AND:*** Requiring multiple pressors ***OR*** addition of mechanical circulatory support devices to maintain perfusion
E Extremis	A patient that is experiencing cardiac arrest with ongoing CPR and/or ECMO, being supported by multiple interventions.	Near Pulselessness Cardiac collapse Mechanical ventilation Defibrillator used	**"Trying to die"** CPR (A-modifier) pH ≤7.2 Lactate ≥5	No SBP without resuscitation PEA or refractory VT/VF Hypotension despite maximal support

Diepen et al. 2019

45

Cardiogenic Shock Definition

Goals of clinical phenotyping CS:

- Define urgency of decision-making and intervention
- Aid diagnosis of the underlying etiology
- Guide prognostication
- Steer the mode of therapeutic intervention

46

ECMO Indications for Cardiac Failure

- Cardiogenic shock
  - ✓ Acute Myocardial Infraction
  - ✓ Myocarditis
  - ✓ Decompensated chronic systolic heart failure
  - ✓ Post cardiotomy shock
  - ✓ Peripartum cardiomyopathy

47

Device configuration according to hemodynamics

RV failure RAP > 15mmHg PCWP < 18mmHg PAPi < 1	Biv failure RAP > 15mmHg PCWP> 18mmHg PAPi < 1	LV failure RAP < 15mmHg PCWP > 18mmHg PAPi > 1
• Impella RP • Protek Duo RVAD • ECMO • Surgical RVAD	• IABP • ECMO +/- IABP or Impella CP • Impella 5.5 + Protek RVAD or RP • Protek BiVAD • Surgical BiVAD	• IABP • Impella 5.0, 5.5 • Tandemheart • ECMO +/- IABP or Impella CP • Surgical LVAD

48

Thank You

49